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ELECTRIC STEEL

Electric magnetic and non-magnetic steels are used for manufacturing of electrical machinery, instruments, devices, etc. Depending on chemical composition and treatment these steels possess different electrical and magnetic properties.

This Catalogue gives the description of the following magnetic steels: soft-magnet easily magnetized steel which becomes non-magnetic again when the source of magnetic excitation disappears and also hard-magnet steels requiring extensive magnetic field for magnetization and possessing of strong residual magnetism not disappearing even under the action of the reversible magnetic field.

The soft-magnet steels include low-carbon (the USSR Standard ГОСТ 3836-47) and silicon alloy (the USSR Standard ГОСТ 802-54) steels delivered mainly as thin sheet products. The hard-magnet steels include chrome, chrome-tungsten, chrome-cobalt and chrome-cobalt-molybdenum (the USSR Standard ГОСТ 6862-54) steels, which are delivered as bar products of round, square and flat shapes.

Austenitic non-magnetic steels are manufactured according to special technical requirements established by the mutual agreement of the purchaser and the supplier.

SOFT-MAGNET STEELS

The soft-magnet steels are utilized in a weak current technique for manufacturing of measuring instruments, communication equipment, amplifying devices, etc. In heavy current engineering soft-magnet steel is used for manufacturing of generators, current converters, motors and transformers.

LOW-CARBON ELECTRIC SHEET STEEL

Low-carbon electric steel (the USSR Standard ГОСТ 3836-47) is used in manufacturing of electromagnetic instruments, apparatus, etc. and is furnished as a thin sheet product.

The sheets as to their dimensions, allowable tolerances in the thickness, width, length and warping shall conform to the requirements of the USSR Standard ГОСТ 3836-47. The surface finish of the sheets shall conform to the limits of the USSR Standard ГОСТ 914-56 for high grade carbon structural steel sheets.

The low-carbon electromagnetic steel is produced in basic open-hearth or electric furnaces and the chemical composition of the finished sheets shall correspond to the following limits (content of chemical elements, in per cent, maximum)

Carbon	0.04	Phosphorus	0.025
Manganese	0.20	Sulphur	0.030
Silicon	0.20	Copper	0.15

If steel conforms to the prescribed limits of coercive force, then the copper content may be allowed up to 0.30 per cent.

Depending on the magnetic properties the steel is made of the following grades:

GRADES OF STEEL

	0	0A	0AA
Coercive force, oersteds, up to	1.2	1.0	0.8
Maximum magnetic permeability, gaussess oersteds, not less	3500	4000	4500

If obtained maximum magnetic permeability is below the above mentioned limits it cannot be used as a basis for rejection.

The definition of coercive force and magnetic induction of steel is performed on test specimens 20 mm wide and 400 mm long, cut from the middle and extreme parts of the sheet in longitudinal and transversal direction of rolling.

The specimens for testing of magnetic properties are subjected to the repeated annealing at 900° C during two hours without access of air and with slow cooling to the temperature of 600° C. On the agreement between the purchaser and the manufacturer, other methods of heat treatment are allowed which guarantee the necessary values of coercive force.

The magnetic induction of each tested specimen shall conform to the following limits:

Table 1.

Intensity of magnetizing field in ampere/turns for 1 cm length	Symbol of induction	Induction value in gaussess, not less
5	B ₅	13800
10	B ₁₀	15000
25	B ₂₅	16300
50	B ₅₀	17100
100	B ₁₀₀	18100
300	B ₃₀₀	20500
500	B ₅₀₀	21800

Special requirements to the metal are established by the agreement of the parties concerned.

The sheets of low-carbon electric steel are delivered in annealed state, in lots of only one dimension, one heat and of one and the same heat treatment.

The sheets are packed in bundles securely tied with metal straps. The weight of each bundle shall not exceed 80 kg. Each bundle contains sheets of the same dimensions and of only one lot of steel.

The top sheet of each bundle is stenciled with the following data: stamp of the manufacturing plant inspection department, heat number and standard number, grade of steel and sheet dimensions.

Each delivered lot of steel is accompanied with the supplier's certificate containing the following data: date and number of purchaser's order, the USSR Standard number, grade of steel, sheet dimensions, weight of the lot, heat number and the values of coercive force, magnetic induction and maximum magnetic permeability.

SILICON ALLOY ELECTRIC SHEET STEEL

Silicon alloy electric steel (the USSR Standard ГОСТ 802-54) is used in magnetic circuits of electrical machinery, apparatus and instruments. The steel is delivered as hot-rolled and cold-rolled sheet product.

Depending on the degree of alloying, magnetic and electrical properties, the steel is divided into the following grades:

Э 11, Э 12

Э 21

Э 31, Э 34, Э 310, Э 320, Э 330, Э 340, Э 370

Э 41, Э 42, Э 43, Э 44, Э 45, Э 46, Э 47, Э 48

The first digit (1, 2, 3 and 4) in symbols of these steel grades indicates the degree of alloying the steel with silicon:

Table 2.

Degree of alloying	Silicon content. per cent	Average specific weight of steel
(1) - low-alloyed	from 0.8 to 1.8	7.80
(2) - medium-alloyed	over 1.8 to 2.8	7.75
(3) - high-alloyed:		
a) hot-rolled	over 2.8 to 4.0	7.65
b) cold-rolled	over 2.5 to 3.5	7.65
(4) extra high-alloyed	over 4.0 to 4.8	7.55

The second digit (1, 2, 3, 4, 5, 6, 7 and 8) indicates the guaranteed electromagnetic properties:

Specific losses during reversal of magnetism in steel with frequency 50 hertz and magnetic induction in strong fields 1, 2 and 3

Specific losses during reversal of magnetism in steel with frequency 400 hertz and magnetic induction in medium fields 4

Magnetic permeability in weak fields (less than 0.01 ampere turns cm) 5 and 6

Magnetic permeability in medium fields (from 0.1 to 1.0 ampere - turns cm) 7 and 8

The third digit (0) indicates that the steel sheets are cold-rolled.

The electrical steel sheets are delivered in the heat-treated state.

The hot-rolled sheets of low-alloyed and medium-alloyed steels are not subjected to pickling, while the sheets of high-alloyed and extra high-alloyed steels are delivered in pickled condition.

The pickling operation can be performed either before or after heat treatment. On the agreement of the parties concerned the sheets of all steel grades can be furnished either in pickled condition or without pickling. The hot-rolled steel sheets before annealing are subjected to a dressing treatment.

The values of magnetic induction (B) and specific losses (P) for steel grades: 9 11, 9 12, 9 31, 9 41, 9 42, 9 43, 9 310, 9 320 and 9 330 are given in table 3; for steel grades 9 34, 9 340 and 9 44 - in table 4; for steel grades 9 45 and 9 46 - in table 5 and for steel grades 9 370, 9 47 and 9 48 - in table 6.

Table 3.

Grade of steel	Nominal thickness mm	Magnetic induction in gaussies at the intensity of magnetic field ampere turns/cm					Specific loss, watt/kg			Mean specific electrical resistance Ω mm ² /m
		B ₁₀	B ₁₅	B ₂₀	B ₂₅	B ₃₀	P _{10 50}	P _{15 50}	P _{20 50}	
		Minimum					Maximum			
9 11	1.0		15000	16200	17500	19700	5.80	13.4		0.25
9 11	0.50		15000	16200	17500	19700	3.30	7.90		0.25
9 12	0.50		14900	16100	17400	19600	2.80	6.80		0.25
9 21	0.50		14800	15900	17200	19400	2.50	6.10		0.40
9 31	0.50		14600	15700	17000	19000	2.00	4.50		0.50
9 31	0.35		14600	15700	17000	19000	1.80	3.80		0.58
9 41	0.50	13000	14500	15600	16800	18700	1.40	3.20		0.58
9 42	0.50	12900	14400	15500	16700	18700	1.40	3.20		
9 43	0.50	12800	14300	15400	16600	18700	1.25	2.80		
9 41	0.35	13000	14500	15600	16800	18700	1.35	3.20		0.58
9 42	0.35	12900	14400	15500	16700	18700	1.20	2.80		0.58
9 43	0.35	12800	14300	15400	16600	18700	1.05	2.50		0.58
9 310	0.50	15700	17000	18000	19400	20800	1.25	2.80	3.80	0.50
9 320	0.50	16500	18000	18700	19800	20800	1.25	2.80	3.50	0.50
9 330	0.50	17000	18500	19000	19800	20000	1.15	2.50	3.50	0.50
9 310	0.35	15700	17000	18000	19000	19800	1.05	2.30	3.20	0.50
9 320	0.35	16500	18000	18700	19500	20000	1.00	2.20	3.20	0.50
9 330	0.35	17000	18500	19000	19500	20000	0.90	1.90	2.80	0.50
9 330	0.35	17000	18500	19000	19500	20000	0.80	1.70	2.60	0.50

Table 4.

Grade of steel	Thick- ness of sheet mm	Specific loss, watt/kg		Magnetic induction gauss-		P ₂₅	Specific electrical resistance (ohm mm ² /m)
		P _{15 100}	P _{20 100}	B ₁₅	B ₂₀		
		Maximum		Minimum			
9 34	0.35	13.0	21.0	11500	13000	1450	0.50
9 340	0.35	12.0	21.0	11500	15200	1700	0.50
9 340	0.20	7.0	12.0	11000	15200	16700	0.50

Table 4 (Continuation).

Grade of steel	Thick- ness of sheets <i>mm</i>	Specific loss <i>watt/kg</i>		Magnetic induction gaussses			Specific electrical resistance <i>Ohm mm²/m</i>
		<i>P</i> ₁₀₀	<i>P</i> ₁₀₋₁₀₀	<i>B</i> ₃	<i>B</i> ₁₀	<i>B</i> ₂₁	
Maximum		Minimum					
9-44	0.35	10.7	19.0	11800	12900	14300	0.57
9-44	0.20	7.20	12.5	11800	12800	14200	0.57
9-44	0.15	6.80	11.7	11600	12800	14100	0.57
9-44	0.10	6.00	10.5	11500	12700	14000	0.57

Table 5.

Grade of steel	Thickness of sheets <i>mm</i>	Magnetic induction in gaussses at the intensity of magnetic field <i>ampere turns/cm</i>			Specific electrical resistance <i>Ohm. mm². m</i>
		B _{0.002}	B _{0.001}	B _{0.005}	
		Minimum			
9-45	0.35	1.20	2.60	7.7	0.55
9-46	0.35	1.50	3.30	8.8	0.55
9-45	0.20	1.30	2.80	7.0	0.55
9-46	0.20	1.60	3.50	8.8	0.55
9-45	0.15	1.30	2.80	7.0	0.55
9-46	0.15	1.60	3.50	8.8	0.55
9-45	0.10	1.30	2.80	6.0	0.55
9-46	0.10	1.70	3.50	8.0	0.55

Table 6.

Grade of steel	Thickness of sheets mm	Magnetic induction in gaussses at the intensity of magnetic field ampere turns/cm							Specific electrical resistance	
		B _{0.1}	B _{0.2}	B _{0.3}	B _{0.4}	B ₁	B ₅	B ₁₀	Ohm mm ² /m	
									Minimum	Minimum
9 370	0.35	1400	5000	9000	10400	11600	10030	17600	0.47	
9 47	0.35	300	1000	3800	6300	6600	11800	12900	0.55	
9 48	0.35	400	1400	4800	6200	7400	12030	12900	0.55	
9 370	0.20	800	2000	6500	7600	8000	13500	16000	0.47	
9 47	0.20	250	800	3800	5300	6000	11700	12800	0.55	
9 48	0.20	350	1200	4700	6000	7300	11900	12800	0.55	
9 47	0.15	230	650	3500	5100	6400	11700	12800	0.55	
9 48	0.15	280	850	4500	5800	7000	11800	12800	0.55	
9 47	0.10	230	650	3500	5100	6400	11700	12700	0.55	
9 48	0.10	280	850	4500	5800	7000	11800	12700	0.55	

The specific losses in steel after ageing shall not exceed the values prescribed in Tables 3 and 4 by more than:

for low-alloyed steel grade 911	7 per cent
for low-alloyed steel grades 912	9 per cent
for medium- and high-alloyed steels	6 per cent
for extra high-alloyed steel	3 per cent

The ageing test specimens are heated during 120 hours: specimens of low-alloyed, medium-alloyed and high-alloyed steels - at the temperature of $120 \pm 6^\circ \text{C}$, and extra high-alloyed steel - at the temperature of $150 \pm 10^\circ \text{C}$.

It is guaranteed that the electric sheet steel shall stand during the test for brittleness, the following minimum of number of bends depending on steel grades and sheet thickness.

Table 3

Grade of steel	Nominal thickness of sheets mm	Minimum number of bends	Grade of steel	Nominal thickness of sheets mm	Minimum number of bends
911	1.0	7	944	0.10	4
911, 912, 921	0.50	10	945, 946, 947, 948	0.35	1.5
931	0.50	4	945, 946, 947, 948	0.20	2
931, 934	0.35	5	945, 946, 947, 948	0.15	3
941, 942, 943	0.50	1	945, 946, 947, 948	0.10	4
941, 942, 943, 944	0.35	1.5	9310, 9320, 9330	0.50	3
944	0.20	2	9310, 9320, 9330, 9340, 9370	0.35	5
944	0.15	3	9340, 9370	0.20	4

The sheets of the electric steels are manufactured to the dimensions indicated in Table 8 with the following permissible variations in thickness:

Table 8

Grade of steel	Thickness mm	Width mm	Length mm	Permissible variations in thickness, mm
911	1.0	750	1500	0.10
	1.0	800	1720	
	1.0	1000	2000	
911, 912, 921	0.5	600	1200	0.05
	0.5	670	1340	
	0.5	750	1500	
	0.5	800	1720	
	0.5	1000	2000	
931	0.5	750	1500	0.05
	0.5	800	1720	
	0.5	1000	2000	

Table 8 (Continuation).

Grade of steel	Thickness mm	Width mm	Length mm	Permissible variations in thickness, mm
931, 934, 941				
942, 943, 944	0.35	750	1500	0.04
945, 946, 947				
948				
941, 942, 943	0.35	1000	2000	
	0.5	600	1500	0.03
9310, 9320, 9330	0.5	750	1500	0.04
9310, 9320, 9330	0.35	240	1500	0.02
9340, 9370	0.35	750	1500	0.03
9340, 9370	0.20	240	1500	0.02
	0.5	750	1500	
941, 942, 943	0.5	860	1720	0.05
	0.5	1000	2000	
	0.20	700	720	
	0.20	700	1400	
944, 945, 946	0.15	700	720	0.02
947, 948	0.15	700	1400	
	0.10	700	720	
	0.10	700	1400	

At the purchaser's request the hot-rolled sheets of extra high-alloyed electric steel intended for manufacture of power transformers and large electrical machinery are delivered with permissible variations in thickness: for sheets 0.5 mm thick -- permissible variation is ± 0.04 mm and for sheets 0.35 mm thick -- permissible variation is ± 0.03 mm.

The variety between maximum and minimum thickness at different points of one and the same sheet shall not exceed the following limits:

Table 9.

Thickness of sheets mm	Hot-rolled sheets mm	Cold-rolled sheets mm
1.0	0.15	
0.42 0.50	0.08	0.04
0.30 0.35	0.05	0.03
0.20	0.04	0.02
0.15 0.10	0.03	

The variations in width and length of sheets are allowed plus 1.0 per cent.

The sheets of electric steel are delivered square cut with a smooth surface free from rust or scale.

Standard number, grade of steel, sheet dimensions and lot number shall be stenciled on the top sheet of each bundle.

Each delivered lot of steel is accompanied with a supplier's certificate containing the following information: grade of steel, weight and number of lot, sheet dimensions, the results of all tests prescribed by the Standard, date of delivery and the USSR Standard number.

HARD-MAGNET STEEL

Hard-magnet steel is used for manufacturing of permanent magnets. It is furnished in shape of round, square and flat cross-sections according to the USSR Standard ГОСТ 6862-54.

The grades of steel and chemical composition are given in Table 10.

Table 10.

Grade of steel	Chemical composition, per cent							Nickel maximum
	Carbon	Chromium	Tungsten	Cobalt	Molybdenum	Manganese	Silicon	
EX	0.95-1.10	1.30-1.60	-	-	-	0.20-0.40	0.17-0.40	0.30
EX 3	0.90-1.10	2.80-3.60	-	-	-	0.20-0.40	0.17-0.40	0.30
EX 7 B 6	0.68-0.78	0.30-0.50	5.20-6.20	-	-	0.20-0.40	0.17-0.40	0.30
EX 5 K 5	0.90-1.05	5.50-6.50	-	5.50-6.50	-	0.20-0.40	0.17-0.40	0.30
EX 9 K 15 M	0.90-1.05	8.00-10.0	-	13.5-16.5	1.20-1.70	0.20-0.40	0.17-0.40	0.30

The variations in chemical composition are permitted provided the steels conform to the limits of magnetic properties and other requirements.

It is guaranteed that the electrical properties of magnetic steel conform to the limits prescribed in Table 11, as to the residual induction (B_r), to coercive force (H_c) and the value of product of these two characteristics ($B_r \cdot H_c$) in specimens subjected to heat treatment and artificial ageing. The hardness of steel in the state of delivery is also shown in the same Table.

Table 11.

Grade of steel	Residual induction B_r , gauss	Coercive force H_c , oersteds	The product $B_r \cdot H_c$	Hardness of steel	
				Brinell hardness, at $P = 3000 \text{ kg}$ $d = 10 \text{ mm}$	Diameter of impression, mm
EX	9000	58	550000	241-247	3.8-4.2
EX 3	9500	60	600000	285-229	3.6-4.0
EX 7 B 6	10000	62	650000	324-255	3.4-3.8
EX 5 K 5	8500	100	900000	344-269	3.3-3.7
EX 9 K 15 M	8600	170	1400000	344-285	3.2-3.6

For steel of round cross-section of diameters 18, 20, 22, 25, 28 and 30 mm, square 20 mm and flat steel 12 - 30, 12 - 35, 12 - 40, 12 - 48, 12 - 50, 14 - 35, 16 - 30 and 16 - 40 mm the limits of magnetic properties can be decreased by 5 per cent. For steel of round cross-section of diameters 32, 35, 36, 40, 45, 48, 50, 55, 60, 65 and 70 mm and flats 20 - 35, 20 - 40 and 25 - 35 mm the limits of magnetic properties can be decreased by 10 per cent, provided that the testing is performed on specimens possessing the cross-sections correspondingly equal to those of round and flats of the steel.

On the agreement of the parties concerned the decrease in values of residual induction by 5 per cent and coercive force by 10 per cent is allowed provided that the value of product of these characteristics ($B_r \cdot H_c$) shall not be less than the limits prescribed in Table 11.

The magnetic steel is manufactured to the dimensions shown in Table 12.

Table 12.

Round steel mm		Square steel mm		Flat steel mm		
Diameter	Tolerance (%)	Side of square	Tolerance (%)	Thickness and width of flats	Tolerance (%)	
					in thickness	in width
8	0.5	10	0.5	6 - 18	0.5	1.0
10	0.5	20	0.7	6 - 22	0.5	1.0
12	0.6			6 - 25	0.5	1.3
14	0.6			8 - 12	0.5	0.8
16	0.7			8 - 16	0.5	1.0
18	0.7			8 - 20	0.5	1.0
20	0.7			8 - 25	0.5	1.3
22	0.8			10 - 16	0.6	1.0
25	0.9			10 - 18	0.6	1.0
28	0.9			10 - 20	0.6	1.0
32	1.1			10 - 40	0.6	1.8
36	1.2			12 - 30	0.6	1.3
40	1.4			12 - 35	0.6	1.8
45	1.4			12 - 40	0.6	1.8
50	1.4			12 - 48	0.6	2.0
55	1.6			12 - 50	0.6	2.0
60	1.6			16 - 30	0.8	1.3
70	1.6			16 - 40	0.8	1.8
				20 - 35	0.8	1.8
				20 - 40	0.8	1.8
				25 - 35	1.0	1.8

It is guaranteed that the ovality of round bars shall not exceed 0.75 of tolerance in diameter of bars counting from the nominal dimensions. The local camber of bars shall not exceed 6 mm per linear meter, and the total camber shall not exceed the product of local camber per linear meter multiplied by length of the bar in meters.

The difference of diagonals (rhomb form) at one cross-section of the strip shall not exceed the tolerance in width of the strip.

The surface of bars shall be free from cracks, laps, scale and burrs. The local defects can be removed by chipping or grinding within the limits of permissible variations in cross-sections of bars. Only one cleaning is allowed in one cross-section of the bar.

The removal shall not be required of minor scratches, dents and ripple marks not exceeding one half of the permissible tolerance.

Steel bars and flats are delivered in lots consisting of one grade of steel, one heat and one and the same heat treatment.

Steel bars and flats up to 25 mm in diameter or thickness shall be furnished in bundles securely tied with at least two straps.

The end face of each bar and flat in diameter or thickness over 25 mm is stamped with grade of steel and heat number. In addition to that, the ends of steel bars and flats are painted with the following colours: for chromium steel - green paint, tungsten - black paint, and cobalt - bronze paint.

The weight of the bundles is established by the agreement of the parties concerned.

A metal tag is attached to each bundle containing the following data: grade of steel, heat number and bars and strips dimensions.

Each delivered lot of steel is accompanied by the supplier's certificate in which are indicated:

- date of manufacturing and heat number,
- weight and number of the lot,
- chemical composition of steel,
- results of all the tests performed on this steel,
- the USSR Standard number for steel delivery.

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